744

VOLUME 81 SEPARATE No. 744

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

JULY, 1955

SYNTHESIS OF RAINFALL INTENSITY-FREQUENCY REGIMES

by David M. Hershfield, Leonard L. Weiss, and Walter T. Wilson, A.M. ASCE

HYDRAULICS DIVISION

{Discussion open until November 1, 1955}

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

THIS PAPER

--represents an effort by the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final date on which a discussion should reach the Manager of Technical Publications appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying "Publication Procedure for Technical Papers" (Proceedings Paper No. 290). For free copies of this Paper—describing style, content, and format—address the Manager, Technical Publications, ASCE.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

SYNTHESIS OF RAINFALL INTENSITY-FREQUENCY REGIMES

David M. Hershfield,[1] Leonard L. Weiss,[2] and Walter T. Wilson,[3]
A.M. ASCE

ABSTRACT

A problem of importance to engineers is the lack of recording rain-gage data in many areas where local drainage systems must be designed. This preliminary report describes an objective method for estimating short-duration rainfall intensities from usually-available climatic data. A nomogram for estimating the 2-year 1-hour rainfall from the following parameters is presented: mean annual precipitation, mean annual number of thunderstorm days, mean annual number of days with precipitation, and the mean of the annual series of maximum daily precipitation amounts. Tests with independent foreign data indicate an average error of about 20 percent in estimates of 2-year 1-hour rainfall.

Rational Basis of Method

In attacking the problem of synthesizing the rainfall intensity-frequency regime for localities lacking short-duration rainfall data, several approaches were considered. The physical approach deals with storm structure and dynamics and its parameters include moisture content of the air and thermodynamic stability of air with respect to vertical movement, cooling and condensation. These parameters are usually available only at places which already have adequate rainfall observations. The synoptic approach considers such variables as the incidence and speed of movement of weather fronts and Lows. The approach showing the most promise uses climatic indices; mean annual precipitation, mean annual number of days of precipitation, mean annual number of thunderstorm days, and the mean of the annual maximum calendar or observational day precipitation amounts. These indices of the physical factors that produce intense short-duration rainfall serve jointly as an empirical measure of it.

Mean annual precipitation is, of course, imperfectly correlated with moisture charge, but must necessarily have some relation to it. Thunderstorm incidence is an index to stability, and examination of many records shows that the highest hourly rainfall intensities are associated with thunderstorms. The mean annual number of days with precipitation is inversely related to the average intensity during stormy periods. The fourth index is a measure of daily precipitation intensity, which is correlated in a complicated way with hourly intensity.

Discussion of Diagram

The accompanying diagram, figure 1, shows the present stage of development of the empirical relationship of 2-year 1-hour rainfall (the

1, 2, 3. U. S. Weather Bureau, Washington, D. C.

amount of hourly rainfall equalled or exceeded on the average once in two years) to the climatic indices named above. The average length of record of the 134 U. S. first-order Weather Bureau stations used to define this relationship is 40 years. Mean annual precipitation, mean annual number of thunderstorm days, and mean annual number of days with precipitation of 0.01 inch or more were taken from the Weather Bureau publication, Local Climatological Summary with Comparative Data. Hourly and daily precipitation data were taken largely from Weather Bureau forms 1001.

For convenience in using the diagram, it can be entered at the upper or lower right with mean annual precipitation expressed either in inches or millimeters. Use of the same ordinates for both systems involves an almost trivial correction, but one that has been made by compensation in the positions of the lines representing the number of days of precipitation, on the left side of the diagram.

In deriving the diagram it was convenient to use the annual series instead of the partial duration series. To convert to the partial duration series, which is based on all the high values of precipitation instead of only one per year, an empirically defined factor of 1.09 is included in the chart. The standard error of estimate of this factor is 0.04 inch in the final answer.

Because many tabulations of precipitation show calendar or observational day instead of the maximum precipitation in any 1440-minute (24-hour) period, the diagram includes the appropriate conversion factor, empirically defined as 1.13, with a standard error of estimate of 0.02 inch in the final answer. The diagram gives maximum 60-minute (not clock-hour) rainfall.

Discussion of Data

Nearly all the data used in deriving this diagram came from stations manned full-time by professional observers. The number of days of precipitation above the nominal bases given is naturally higher at such stations than would be observed by part-time or less careful observers. No determination has been made of the average magnitude or possible consistency of this bias.

It has been determined that the definition of thunderstorm days and the standards of observing and reporting them have been dependably uniform at commissioned meteorological stations throughout the world for the last 50 years. There are, undoubtedly, instances of thunderstorm rainfall occurring without the thunder being heard, and more instances of hearing distant thunder without any rain falling at the place of observation. The diagram does not assume a one-to-one relationship. The average error is minimized by the fortunate fact that the area of audibility of thunder is usually consistently related to the size of the rain-covered area in a thunderstorm,(1) and that the intensity of electrical phenomena is related physically to the intensity of rainfall.(2)

Quality of Relationship

Figure 2 shows the scatter diagram of estimated versus observed 2-year 1-hour rainfall for the stations used in deriving the relationship. The standard error of estimate is about 0.11 inch, and the correlation coefficient is about 0.98. Tests with foreign data have shown an average error of about 20 per cent. In areas where daily precipitation data are not available, an estimate of the 2-year 1-hour values can be made with only three parameters, namely, mean annual precipitation, mean annual number of thunderstorm

days, and mean annual number of days with precipitation equal to or greater than 0.01 inch. The standard error of estimate based on observed U. S. values of these three parameters is 0.20 inch.

Status of Project

Present work includes efforts to refine the structure of the empirical relationship and testing of additional parameters. Perhaps a different base or combination of bases for days of rain will improve it. There are indications that mean seasonal rainfall rather than mean annual precipitation should be used as a parameter. The optimum season is different in different parts of the world.

It should be possible to add to the hydrologic value of this relationship by incorporating a means for showing the seasonal variation in the rainfall intensity-frequency regime.

Other Durations and Frequencies

For durations other than one hour and 24 hours, values of intensity may be computed[3] by using the following average ratios to the 60-minute intensity:

10 min.	3.0
15 min.	2.3
30 min.	1.5
90 min.	.75

Some geographic variation seems to exist, with indications that the ratio for very short durations is higher in the interior of continents than along the upwind coasts which are nearer the moisture source region.

For frequencies other than the 2-year, provisional average values can be given for the ratio of the 5-year and 10-year to the 2-year frequency: 1.4 and 1.7, respectively.[3]

Example of Use of the Graph

At San Juan, Puerto Rico, the mean annual precipitation can be taken as 61 inches, the mean annual number of thunderstorm days as 50, the mean annual number of days of precipitation with 0.01 inch base as 210, and the mean of the annual maximum daily precipitation values of 4.4 inches. To estimate the 2-year 1-hour rainfall for that locality, the graph is entered at the upper right, interpolating the 61 inch annual precipitation value and noting its intersection with the 50 thunderstorm-day line. This ordinate is projected to the left to a point where it intersects the appropriate number of days of precipitation. The highest value given on the diagram is 200, which corresponds to a value read at the bottom of the left side of the diagram of about 1.44 inches per hour. Extrapolation to a reasonable position for 210 days of precipitation per year results in a slight reduction to about 1.42 inches per hour. To incorporate the mean annual maximum daily precipitation, the 1.42 value is projected upward on the diagram to an intersection with 4.4 inches per day. The answer is read to the right and found to be very nearly 2.0 inches for the 2-year 1-hour value.

ACKNOWLEDGMENT

The relationships presented above have been derived in connection with projects undertaken for the Airfields Branch of the Corps of Engineers. The encouragement and support of K. S. Eff is appreciated. A. L. Shands and others in the Hydrologic Services Division have made helpful criticisms and suggestions.

REFERENCES

1. Hydrometeorological Report No. 5, Thunderstorm Rainfall.
2. Compendium of Meteorology, Boston, Mass., 1951, pp. 128-135.
3. United States Weather Bureau Technical Paper No. 24 Part I.

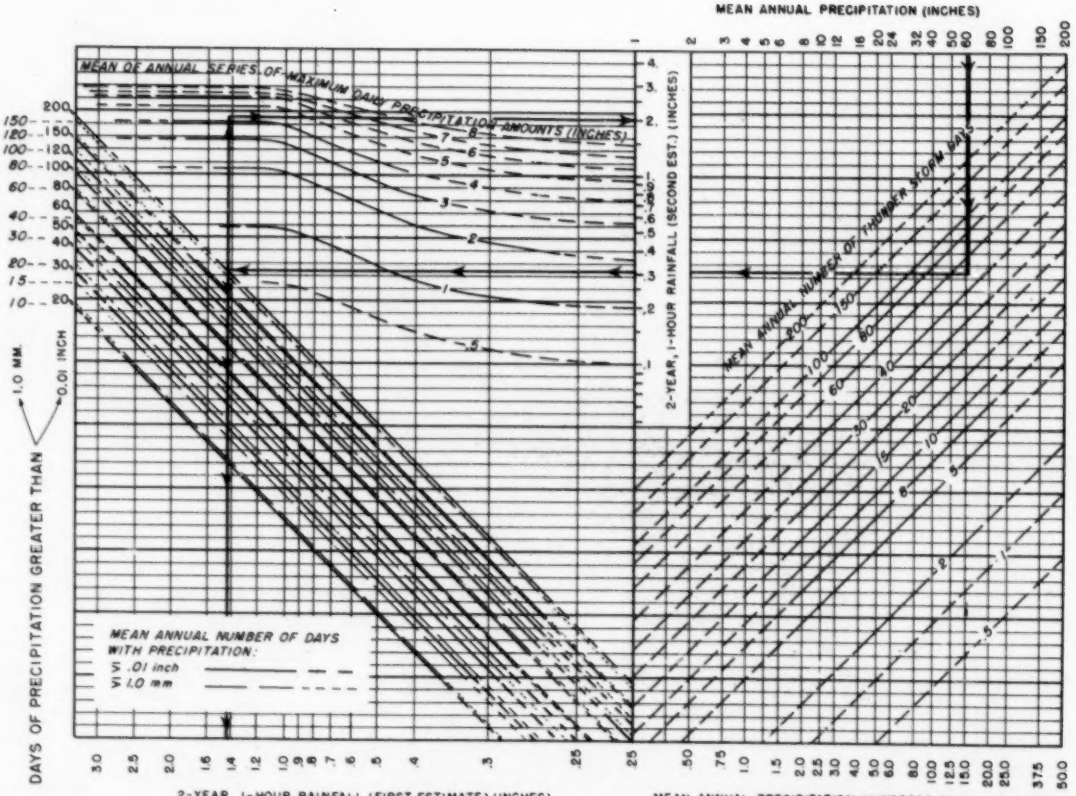

Fig. 1. DIAGRAM FOR ESTIMATING 2-YEAR, 1-HOUR RAINFALL
(Dashed lines are unsupported by data)

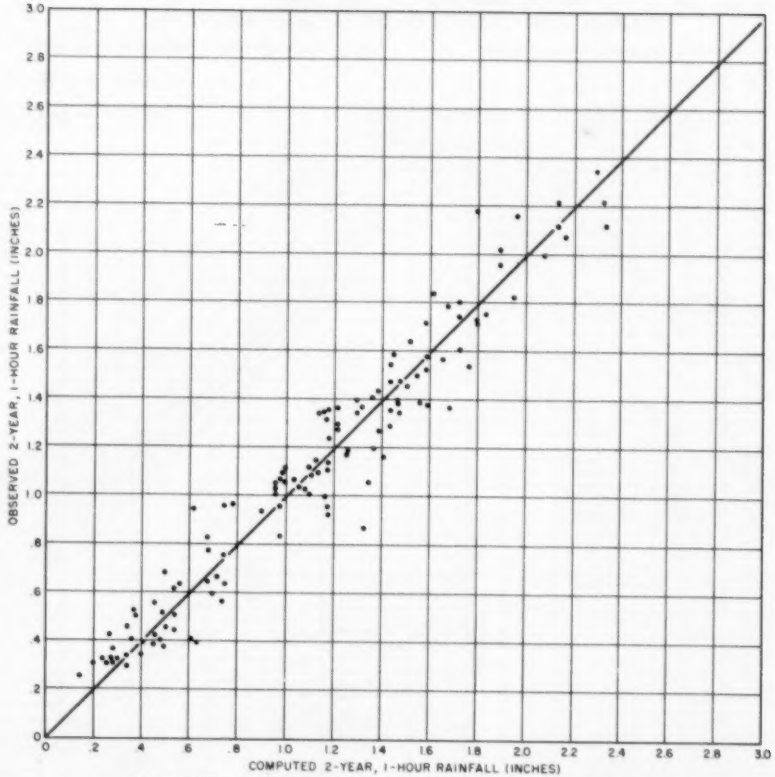

Fig. 2 CORRELATION OF COMPUTED WITH OBSERVED 2-YEAR, 1-HOUR RAINFALL